

Retrofit Visibility Background:

To prevent these retrofits from being installed in a manner that impairs visibility, the Air Resources Board (ARB) and the Division of Occupational Safety and Health (Cal/OSHA) released an interim visibility policy² on October 21, 2009. The interim policy states that off-road vehicles should not be retrofit if a retrofit cannot be installed without creating masking to the front, sides, or rear of the vehicle. 'Masking' means the area where a vehicle operator's vision would be blocked by the retrofit.

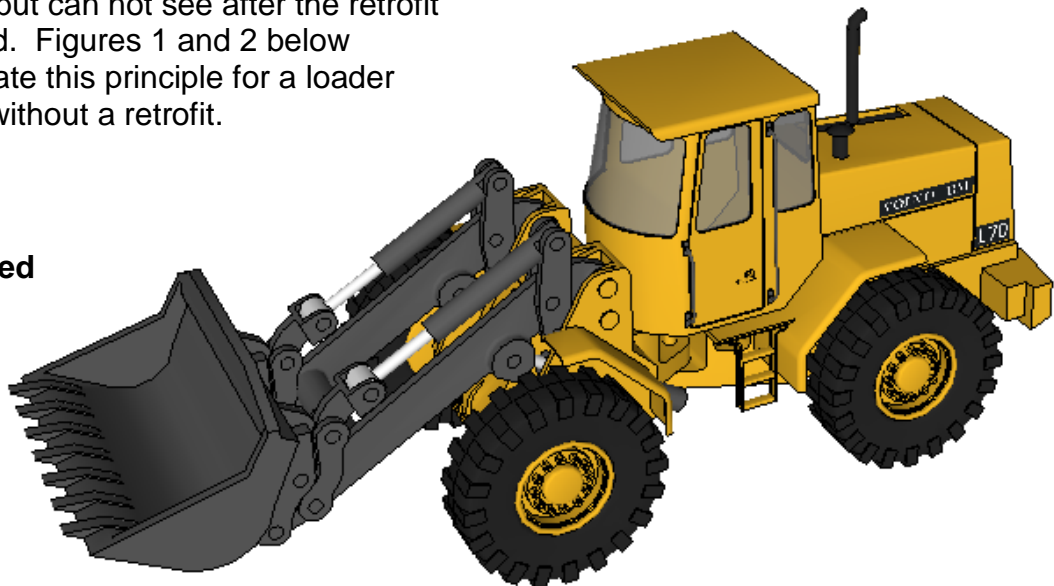
While Cal/OSHA prepares a final regulation that is expected to be adopted in 2011, ARB is releasing this guide to help fleets and installers figure out how vehicles can be retrofit without creating any masking. This document has sections on:

- **Masking Explained**
- **Assessment Overview**
- **Retrofitting Vehicles without Creating Masking**
- **Safety Assessment**
- **Line of Sight Measurements**

Masking Explained

As noted above, masking is the area where vision is blocked. In discussing the interim visibility policy and throughout the course of this document, we will only be considering the masking caused by an exhaust retrofit, not masking caused by other vehicle attachments or the vehicle itself. The masking from a retrofit is defined as the area around a vehicle that an operator could see before the retrofit is installed, but can not see after the retrofit is installed. Figures 1 and 2 below demonstrate this principle for a loader with and without a retrofit.

Fig. 1
Unmodified
Loader



² http://www.arb.ca.gov/msprog/ordiesel/documents/interim_visibility_policy.pdf

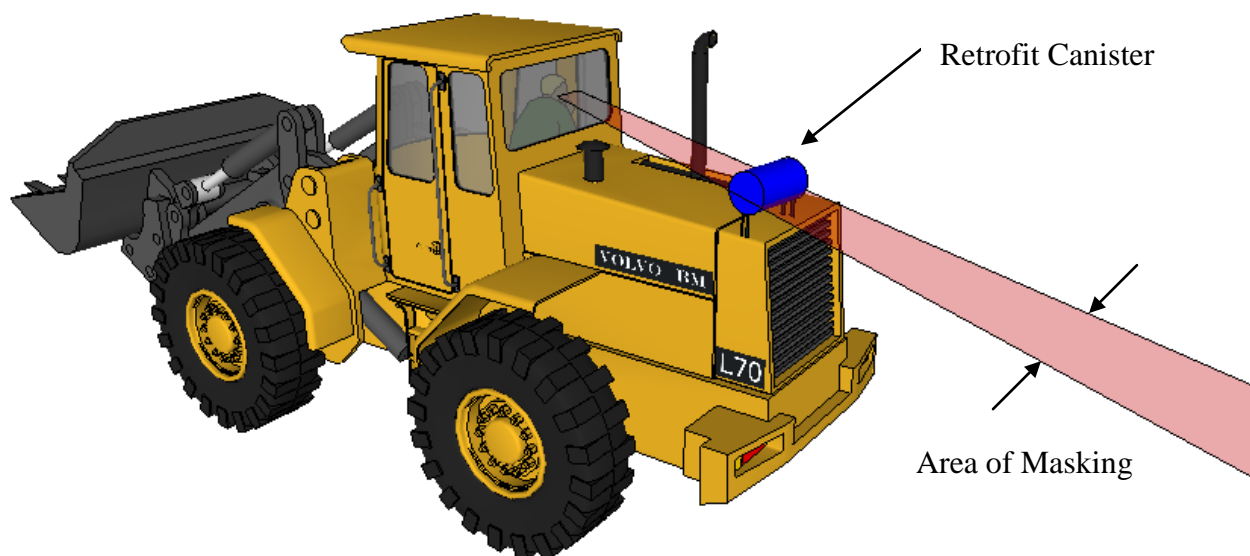


Fig. 2 Retrofit Mounted on Loader

In Figure 2 above, a retrofit (shown in blue) has been mounted on the rear of the loader, and the area of masking it would create for an operator sitting in the seat is shown in red. This is the area the operator can no longer see due to the retrofit.

Safety Assessment

While ARB no longer requires retrofits on off-road diesel vehicles, fleets interested in retrofits can request a safety assessment, where ARB will coordinate the fleet and retrofit manufacturers in looking at the vehicle to determine if a retrofit can be installed in accordance with the interim policy.

To receive an assessment for a vehicle, fleets will need to follow the instructions laid out in this document to (1) analyze whether or not the vehicle can be retrofit with zero masking, (2) fill out the assessment request form, and (3) submit it to ARB so that ARB staff and subsequently the retrofit manufacturers/installers may assess the claim.

Retrofitting Vehicles without Creating Masking

There are several ways to retrofit a vehicle without creating any masking. Not all methods will work on a particular vehicle, and for some vehicles no method may work. Fleets and installers should also note that changes to visibility due to changes to exhaust piping must also be considered. This means that fleets and installers will have to ensure that modifications to the exhaust pipes, in addition to the retrofit canister itself, do not create additional masking; however, they may create the same amount of masking as the unmodified vehicle (e.g. a pipe of the same size in the same location will not be considered additional masking) but they may not create more masking than the original exhaust.

When considering locations to install a retrofit, fleets should also consider whether their choice of location would affect the structural integrity or safe handling (weight and balance) of the vehicle. Retrofits should not be installed where the operator or workers would be exposed to heat from the retrofit that could result in an injury, or where a fire hazard would be created due to proximity to flammable or combustible materials.

Under-hood Installations

Some vehicles may be retrofit by installing the retrofit under the hood or body of the vehicle, completely out of sight of the operator, such as the Hyster 300 shown in Figure 3 below. In such cases where the vehicle profile is unchanged, clearly the retrofit canister is not causing visibility issues. This installation method may not be feasible for all vehicles due to space constraints; vehicles will need to be evaluated for sufficient space under the hood, appropriate engine conditions (if the exhaust can be routed through the location where the retrofit could be placed under the hood), and other factors such as mounting and cooling.

For vehicles that can be retrofit with under-hood installations, the installer should also consider the masking caused by any changes to the exhaust piping. Where the original exhaust can still be used (or a pipe of the same diameter in the same location), this prevents any change to the visibility masking. However, as described on page 5, solutions are possible where a greater exhaust diameter is needed.



Fig. 3 Under-hood Installation on a 2005 Hyster 300

Out-of-Sight Retrofits

Some vehicles may be retrofit without impacting visibility by installing a retrofit in a location that is not in the line of sight of the operator, even if it is not an under-hood installation. In these cases, the retrofit might be placed behind an existing vehicle contour or behind the vehicle hood instead of under it. For the retrofit installed on the rear engine of the scraper in Figure 4 below, the retrofit is clearly visible, but is out of the line of sight of the operator. As with under-hood

installations, the exhaust piping must also be considered when determining masking.

**Retrofit
Installation Out of
Operator Sight**



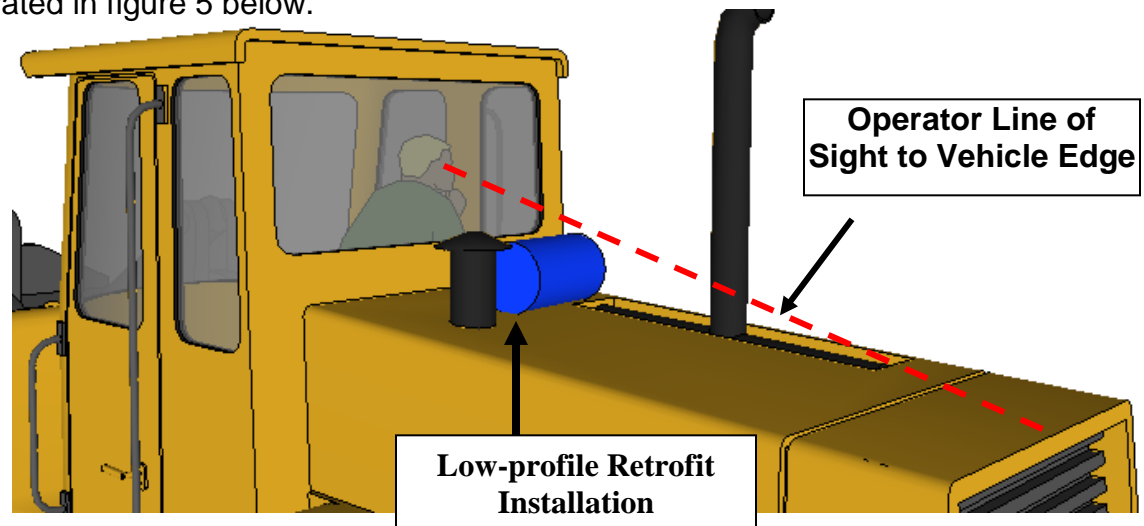
Fig. 4 Retrofit of a 2006 Caterpillar 657E

Retrofits Below Vehicle Profile

Retrofits do not always have to be out of the line of sight of the operators, in some cases they may be in plain view but not block visibility. In these cases, the retrofit is placed below the line of sight of the operator over the edge of the vehicle.

Using the same example loader in the introduction, if the retrofit is placed low to the hood and closer to the cab, and not at the back of the cab and raised on mounts, the retrofit would be below the line of sight of the operator. This is demonstrated in figure 5 below.

**Fig. 5
Retrofit Below
Vehicle Profile**



Alternate Exhaust Configurations

As discussed above, in some instances fleets may be able to install a retrofit under the hood of a vehicle, but not be able to utilize the existing exhaust piping configuration. In such cases, rerouting of the exhaust piping may be necessary,

but the resulting masking from the rerouted exhaust pipes may not exceed that of the original vehicle exhaust. Following the rules shown below may allow installers to move the exhaust piping while not increasing masking:

- If the original exhaust did not interrupt the operator line of sight over the edge of the vehicle, then the modified exhaust must not either.
- If the original exhaust was in the line of sight, and the modified exhaust is the same width as the original exhaust, it must not be closer to the cab than the original exhaust.
- If the modified system requires additional exhaust volume, multiple exhaust pipes with small diameters could be placed in line with each in the direction of the operator's line of sight as shown in figure 6 and 7 below.
- No new exhaust piping may create a visibility masking in an area of the operator's line of sight not previously obstructed. For example, an unmodified vehicle with an exhaust pipe directly behind the vehicle should not be retrofit and modified such that the exhaust pipe is placed in a different direction relative to the operator, even if the masking is reduced.

Fig. 6 Unmodified Exhaust

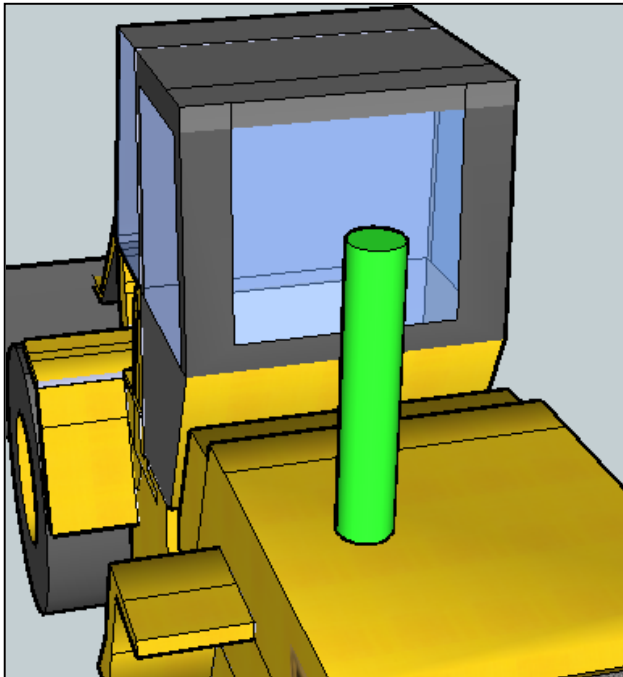
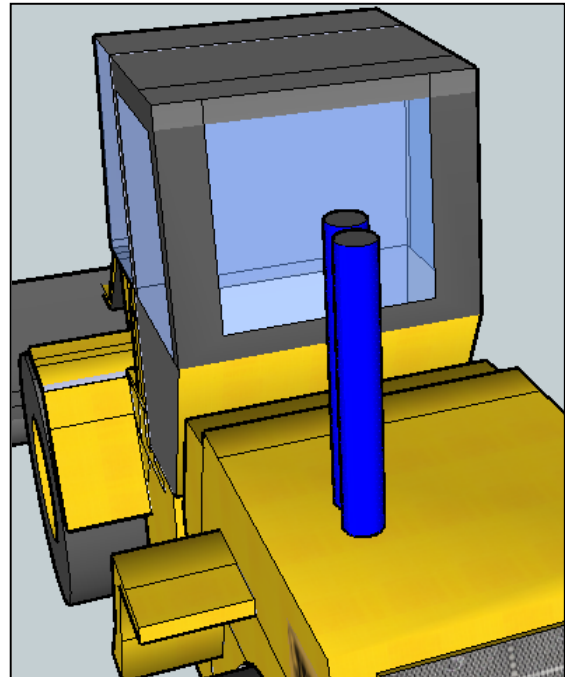


Fig. 7 New In-line Exhaust



Installation Assessment

1. Determine whether there is a retrofit verified for the engine. More information on this process can be found here:
<http://www.arb.ca.gov/msprog/ordiesel/vdecs.htm>
2. If there is one or more verified device, determine whether there is a suitable location on the vehicle where the retrofit is clearly not visible by the operator, such as under the hood, or similar to the 657E scraper in the example of out-of-sight retrofit locations. The fleet may need to work with retrofit manufacturers and/or installers if they are not familiar with exhaust retrofit installations. A list of manufacturers and installers is available at:
<http://www.arb.ca.gov/msprog/ordiesel/vdecs.htm>
3. If an under- hood or out-of-sight retrofit is not possible, in some cases there may be a location where the retrofit could be installed in a location visible to the operator without creating masking, in a location below the operator's line of sight. Locating these areas is outlined on page 9 in the "Line of Sight Measurements" and is optional for the vehicle owner.
4. If there is such a location for the retrofit where there is no visibility impairment, then the vehicle may be retrofit if that location is suitable when considering mounting and exhaust routing, burn or fire hazards, and the structural integrity or safe handling (weight and balance) of the vehicle.

Assessment Process

If the vehicle owner has performed the steps above, and finds no means to retrofit the vehicle, he may decide to move on to other vehicles: filling out the assessment form is only necessary if the fleet wishes receive confirmation from ARB that no manufacturers are able to retrofit the vehicle while following the interim policy. The assessment form is available at
<http://www.arb.ca.gov/msprog/ordiesel/vdecssafety.htm>

When filling out the form, the fleet must list the vehicle and engine information required, as well as submit pictures and schematics of the vehicle with references for size and dimensions.

Retrofit Visibility Masking

The application form requires the vehicle EIN and a list of the retrofits verified for the vehicle. In addition to that information, the fleet must submit pictures and schematics that show, at a minimum:

Vehicle Profile



Engine Compartment Profile



Rear Views of the Vehicle



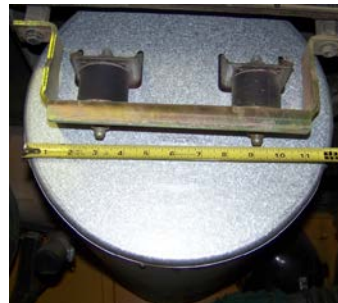
Top View of Engine Compartment



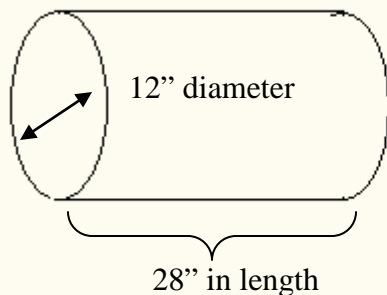
Engine compartment with access doors open



Dimensions of engine components, specifically any muffler components

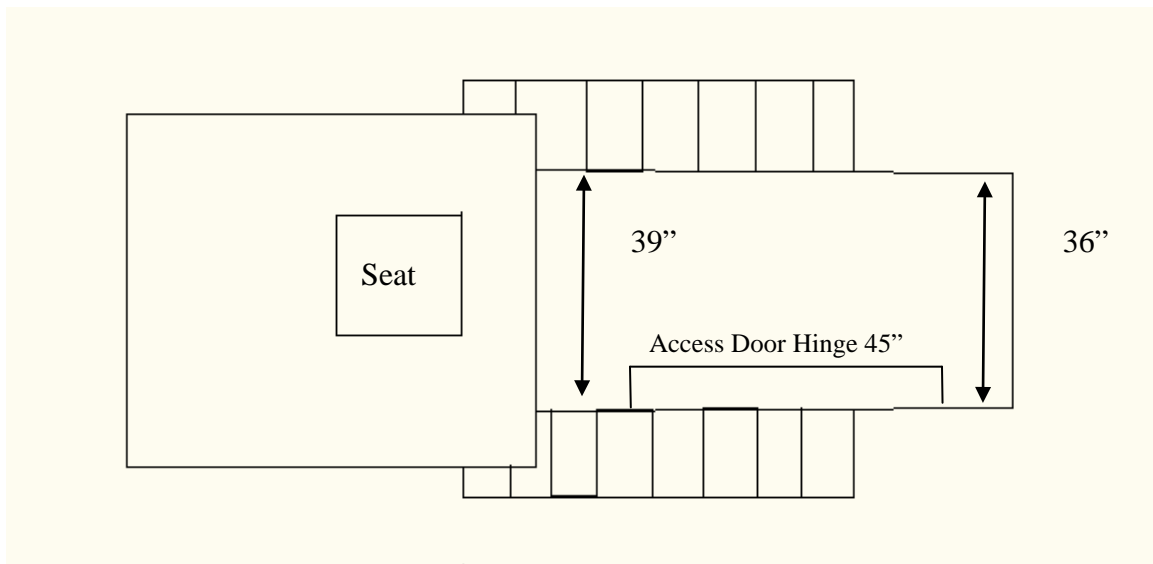
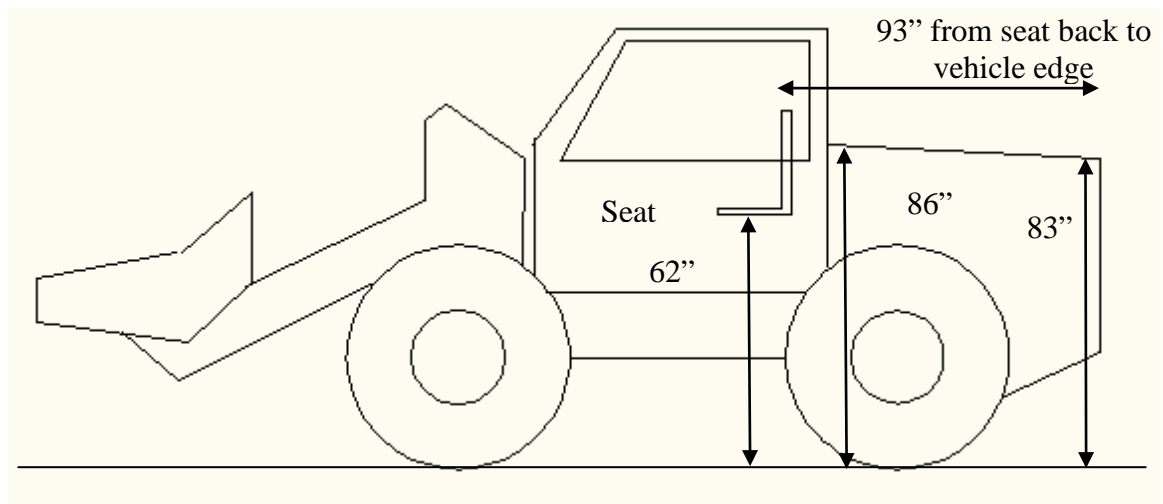


In addition to the above photos, fleets must also show the muffler dimensions and (if possible) the muffler part number, as well as the overall vehicle dimensions relative to the height of the engine compartment and the vehicle seat, as illustrated below.



Muffler Part Number
C5NE9430E

Retrofit Visibility Masking



Line of Sight Measurements

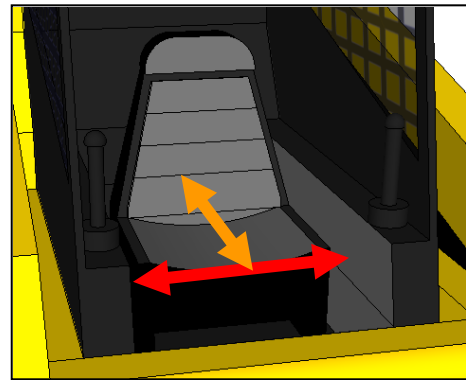
The line of sight measurement process described below is **optional** for fleets completing a visibility assessment request. This method is appropriate when an installation location under the hood or hidden completely by the vehicle body is not feasible, but when there may be an installation location in sight of the operator that does not cause visibility masking. This guide provides step-by-step instruction on finding the operator eye-point and how to determine whether a retrofit installation in sight of the operator causes visibility masking.

Instructions

Finding the operator eye-point will allow a consistent point from which to determine the masking. The operator eye-point is representative of the height and location that an average operator's eye would be when operating the vehicle.

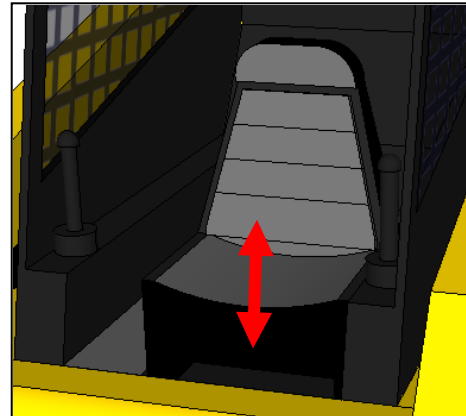
1. Center the seat.

The seat should be centered both in the left-right axis and the back-front axis.



2. Adjust the seat to the center position.

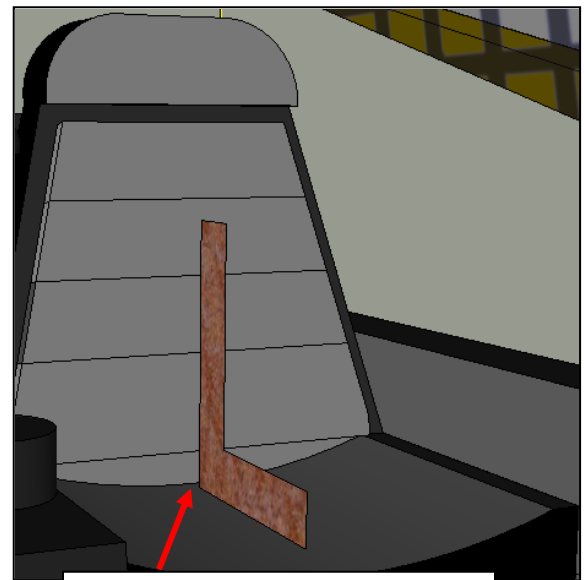
If the seat is adjustable in the vertical direction, either manually or pneumatically, it should be adjusted to the center position. For example, if the seat can be adjusted four inches from the lowest position to the highest, move the seat to the lowest position and then raise it two inches.



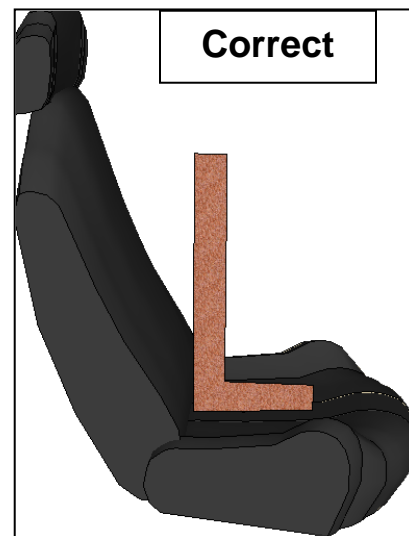
3. Find the center-back of the seat cushion.

To determine the operator eye-point, we will first determine the center-back of the seat cushion. This can be done with an engineering square as shown in the picture. Place the square in the seat in a vertical position, with the square moved as far back as possible while still in a vertical position (see the examples below). To ensure the square is vertical, you may need to use a level or a plumb bob. The bottom corner of the level will define the center-back of the seat cushion.

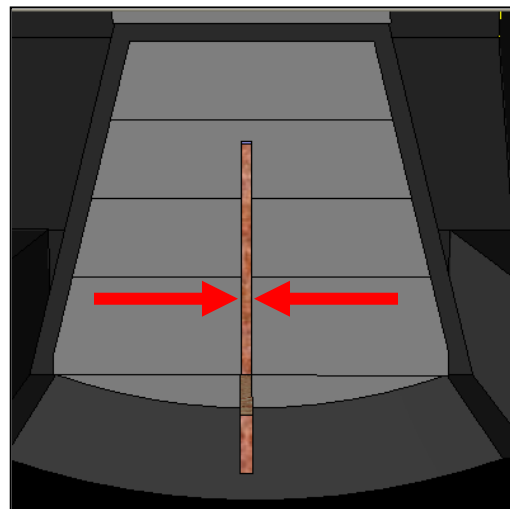
Note that the square should be vertical, and not simply laid against the seat back.



Center-back of the seat.



Additionally the square should be centered horizontally in the seat cushion.



4. Account for seat compression.

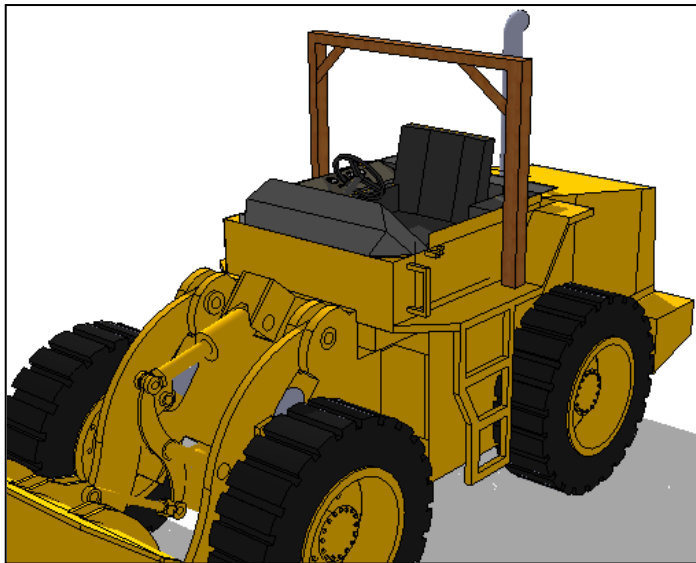
To account for the fact that some seats compress substantially (and therefore the operator sits lower than the initial location of the top of the seat cushion), we will take three measurements and apply them to the operator eye-point

- A. Using a test subject or operator weighing between 160 and 220 lbs, measure the seated height when the subject is sitting upright on a hard flat surface (distance from surface on which subject sits to top of subject's head).
- B. Have the subject sit upright in the operator's seat of the vehicle in question with the seat adjusted to the middle position, and measure the vertical distance from the roof the of the vehicle cab to the top of their head.
- C. Measure the vertical distance from the same point on the vehicle cab to the top of the unloaded seat cushion, again with the seat in the middle position.

The seat compression is:

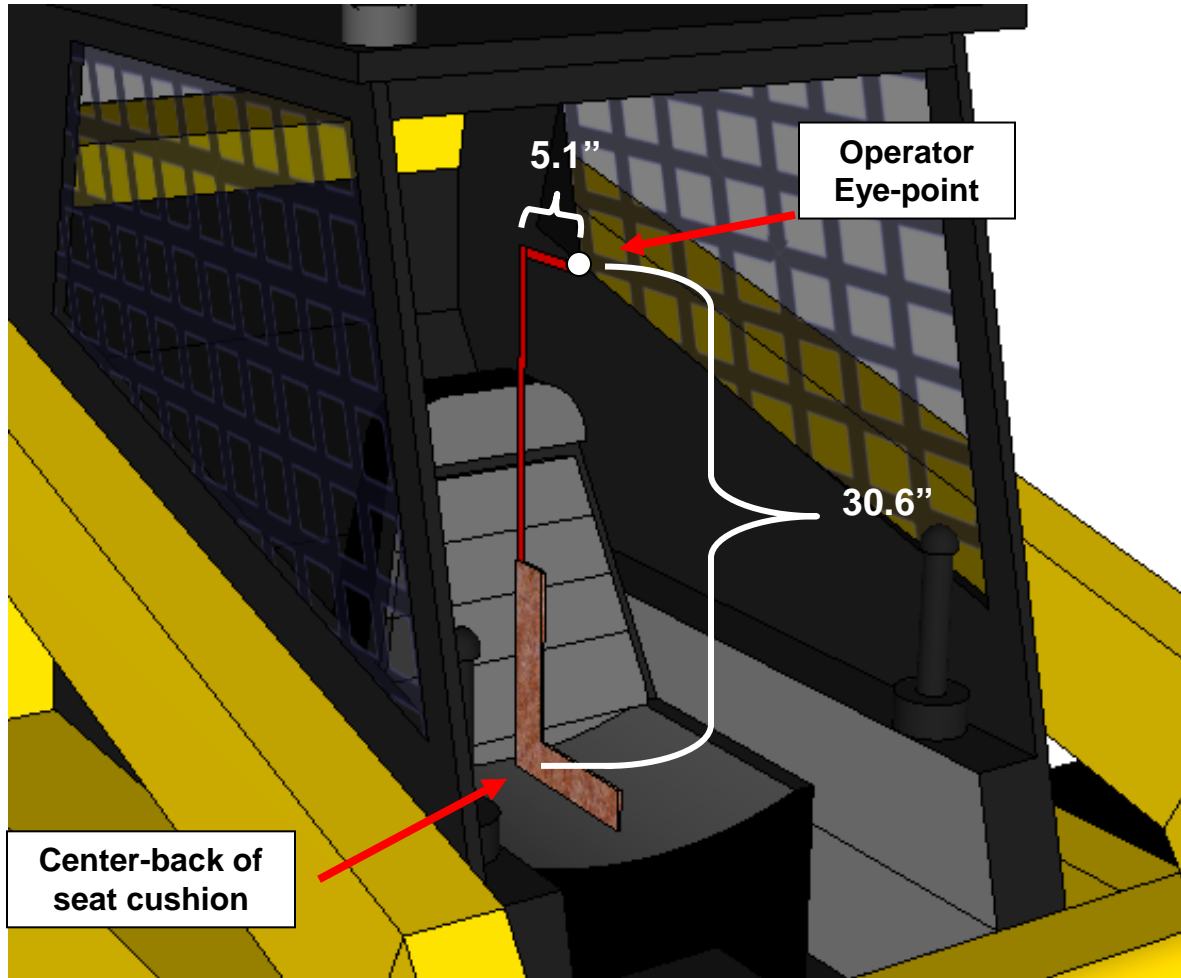
Operator seated height (A) + distance from the vehicle roof to the top of their head in the seat (B) – the distance from the roof to the unloaded seat (C)

For vehicles without a cab, the distance may need to be measured from a clearly defined static point above the operator seat. For example, the test personnel could place a rigid frame over the operator seat to take measurements from, as shown below for the open-cab loader.



5. Define the operator eye-point.

The operator eye-point will exactly be 30.6 inches above the center-back of the seat cushion and 5.1 inches forward, as defined by the engineering square in step 3, **minus** the seat compression found in step 4. The picture below would be accurate if there was no seat compression (the eye-point height is 30.6 inches exactly).

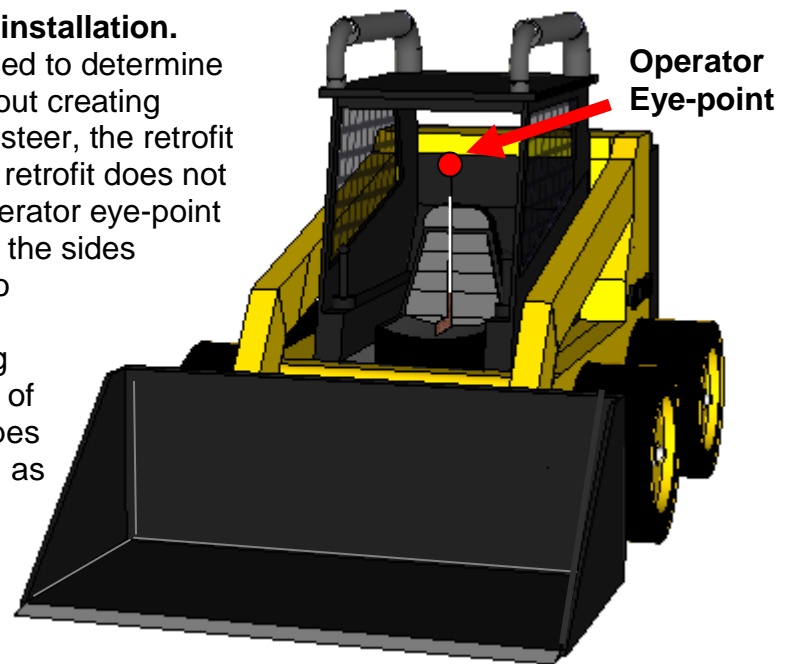


Again, a level or plumb bob should be used to ensure the distance is measured vertically from the center-back of the seat. **Once identified, the operator eye-point reference will be used to determine visibility and take measurements.** The engineer performing the test should use some means to mark the point. One method is to use a device built to sit in the seat and stand 30.6" tall, or hang a plumb bob from the ceiling, or use other methods. One example of a device is shown to the right, where a rod has been mounted on a plate that sits in the operator seat and can be adjusted to stand vertically, and a height of 30.6" is identified by the crossbar.

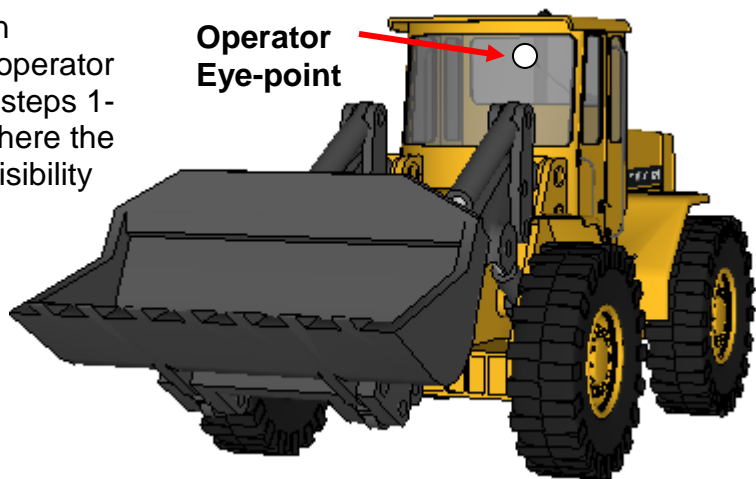


6. Determine suitable locations for an installation.

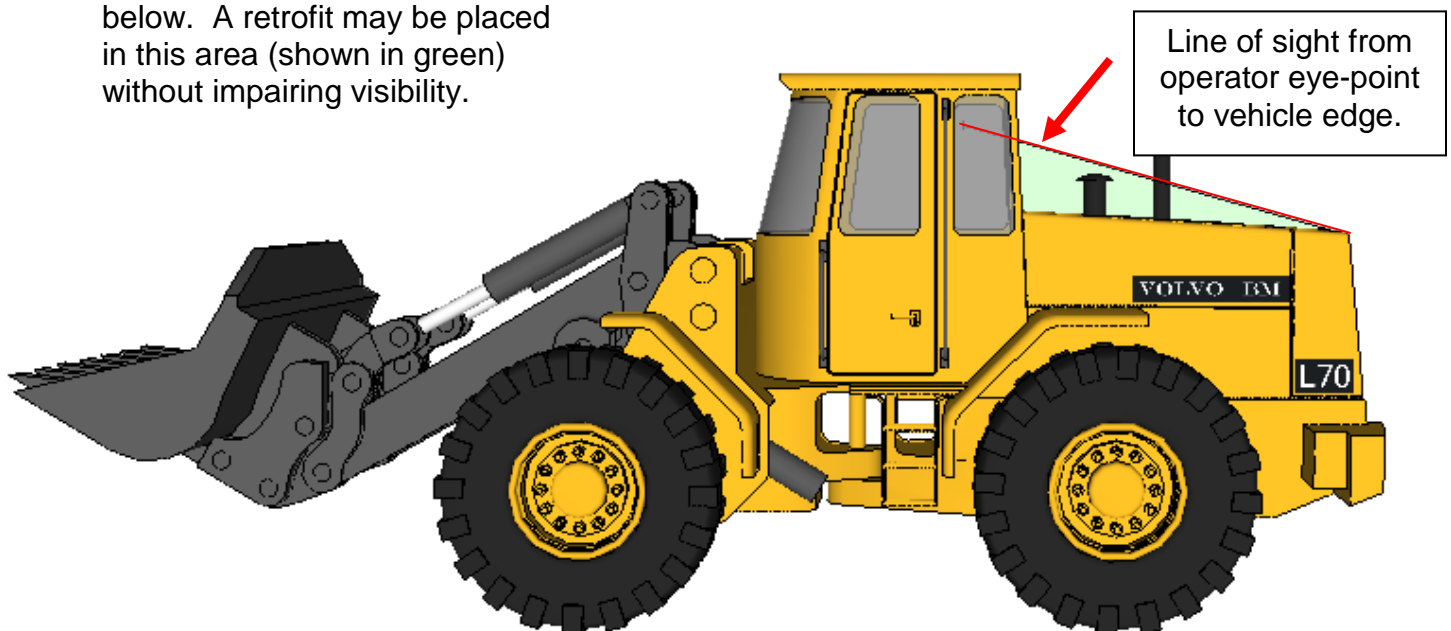
The operator eye-point can then be used to determine where a retrofit could be installed without creating visibility masking. Looking at our skid steer, the retrofit would have to be placed such that the retrofit does not impair the operator's sight from the operator eye-point in any direction, either to the rear or to the sides through the windows. Modifications to the exhaust system will also be considered part of the retrofit, meaning that even if the retrofit was out of sight of the operator eye-point, the exhaust pipes could not create any visibility masking, as explained on page 5.



Using the loader to the right as an example (where determining the operator eye-point has been completed in steps 1-5), you would need to evaluate where the retrofit could be placed to avoid visibility impairment

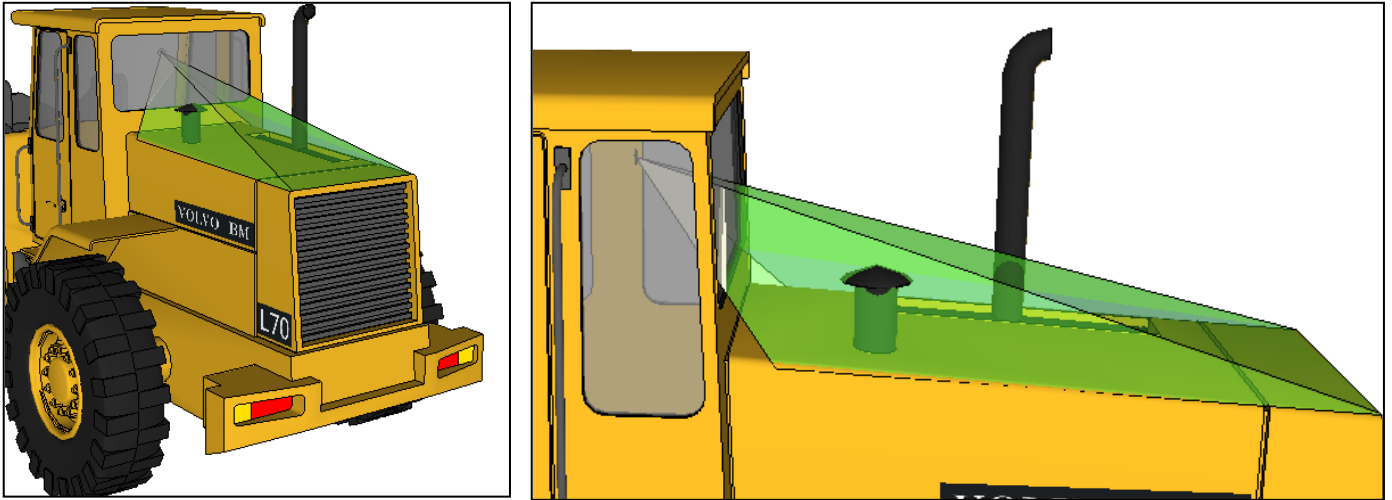


In this case, you might also consider an installation in the triangular area defined by the line from the operator eye-point to the edge of the vehicle, as demonstrated in the figure below. A retrofit may be placed in this area (shown in green) without impairing visibility.

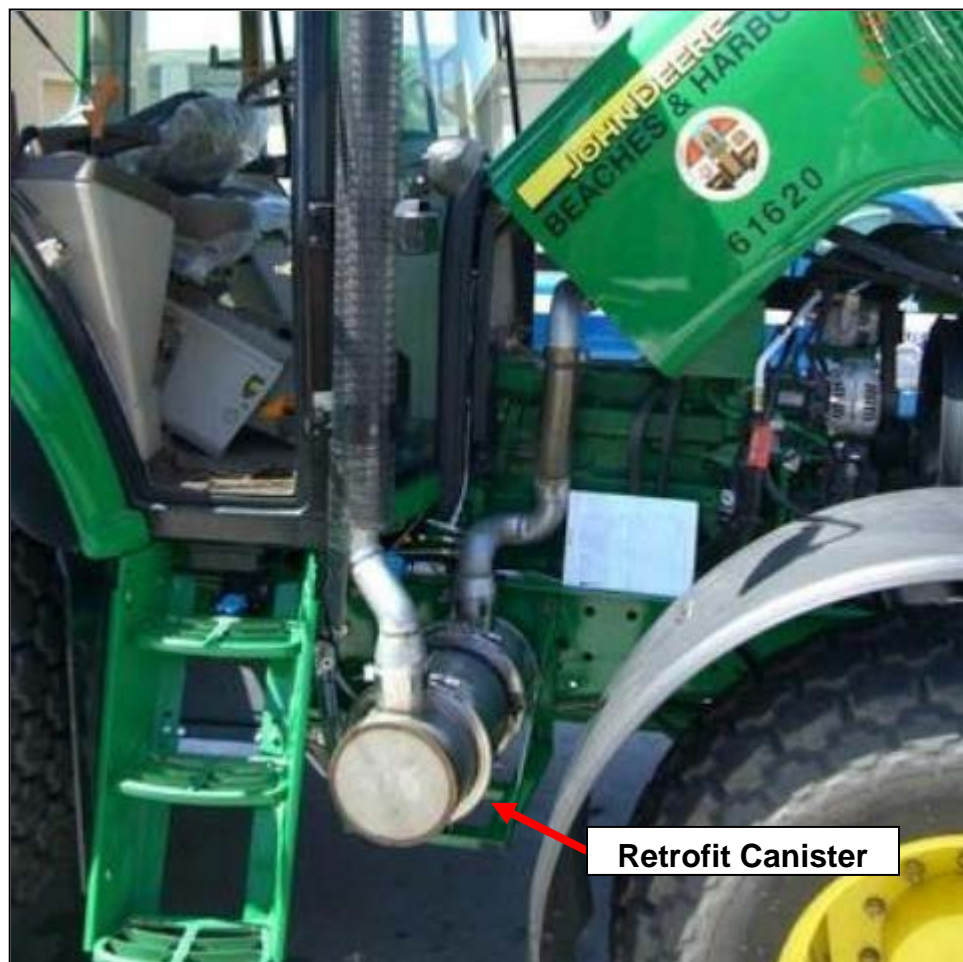


Retrofit Visibility Masking

Expanding on this concept, and drawing lines to the side of the vehicle in the rear direction, we can see an envelope (in green) under which a retrofit could be installed (or where the hood might be modified) on the vehicle body without creating masking.



This may provide options in addition to under-hood installations, or installations such as the John Deere tractor shown below.



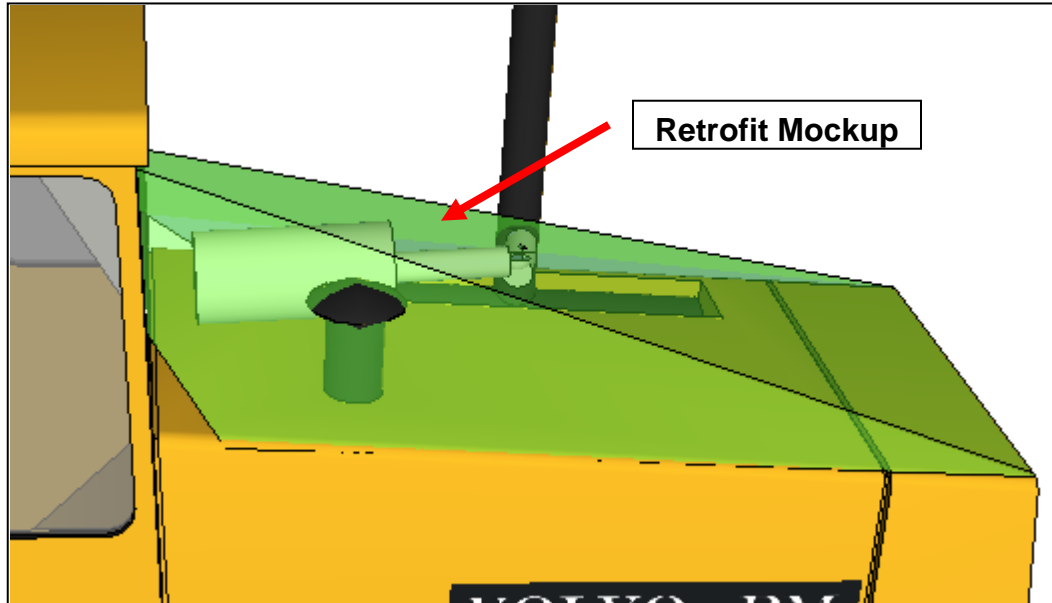
Retrofit Visibility Masking

In the installation on the previous page, the retrofit canister has been placed next to the vehicle body between the wheels and out of sight of the operator. The exhaust from the retrofit has a heat shield installed to prevent a burn hazard and is routed behind an existing vehicle masking in the corners of the operator's cab.

If this process does not clearly demonstrate whether a retrofit could be installed without impacting visibility, the test personnel could use a mockup of a retrofit device to determine whether an installation would create masking. If an individual fleet was performing the test, they might need to contact a representative from the companies that have retrofits verified for the engine to determine an appropriate retrofit mockup size.

For the loader in the previous examples, we will use an example size of a retrofit that is 40" long, and 12" in diameter.

As shown in the diagram, using a mockup of that size, it appears to be possible to install a retrofit on the engine hood below the operator line of sight.



7. Requesting an assessment.

If you cannot determine a suitable location with the assistance of the retrofit manufacturer and/or installer, then you may choose to request a retrofit safety assessment, and provide the necessary information to ARB.